

in magnetization thereof in response to a variation in the magnetic field becomes linear.

[0394] The sense current from the electrode layers **120** and **120** is directly fed to the magnetoresistive layer **54** in the sensitive region E. The direction of the advance of the recording medium is aligned with the Z direction. When a leakage magnetic field from the recording medium in the Y direction is applied, the magnetization direction of the magnetoresistive layer **54** varies, causing a variation in the resistance. The resistance variation is then detected as a voltage variation.

[0395] By using a method, to be discussed later, for manufacturing a magnetoresistive-effect device, the film thickness of the region of the hard bias layer in contact with the multilayer is made thin, and the top surface of the hard bias layer close to the multilayer film is, downwardly, inclined or curved toward the multilayer film as shown in the magnetoresistive-effect devices shown in FIG. 1 through FIG. 14.

[0396] When the top surface of the hard bias layer is projected upward toward the multilayer film in the conventional magnetoresistive-effect device as shown in FIG. 33, a leakage magnetic field or a loop magnetic field takes place around the projected portion, making the magnetization direction of the free magnetic layer less stable.

[0397] If the top surface of the hard bias layer is, downwardly, inclined or curved toward the multilayer film as shown in FIG. 1 through FIG. 14, the generation of the leakage magnetic field and the loop magnetic field is prevented, and the magnetization direction of the free magnetic layer is thus stabilized.

[0398] The manufacturing method for manufacturing the magnetoresistive-effect devices shown in FIG. 1 through FIG. 14 is now discussed referring to the drawings.

[0399] Referring to FIG. 15, a multilayer film **161** of the magnetoresistive-effect device is formed on a substrate **160**. The multilayer film **161** can be any of the multilayer films of the single spin-valve type thin-film devices shown in FIG. 1 through FIG. 5, and FIG. 11 through FIG. 12, the multilayer films of the dual spin-valve type thin-film devices shown in FIG. 6, FIG. 7 and FIG. 13, and the multilayer films of the AMR devices shown in FIG. 8, FIG. 9 and FIG. 14.

[0400] To form the antiferromagnetic layers **30**, **70**, **80**, and **100** in extended forms thereof in the X direction respectively shown in FIG. 4, FIG. 5, FIG. 10, and FIG. 11, an etch rate and etch time are controlled to leave the lateral portions of the antiferromagnetic layers **30**, **70**, **80**, and **100** when the sides of the multilayer film **161**, shown in FIG. 15, are etched away.

[0401] When the multilayer film **161** is a multilayer film for a single spin-valve type thin-film device or a dual spin-valve type thin-film device, the antiferromagnetic layer in the multilayer film **161** is preferably made of a PtMn alloy, or may be made of an X—Mn alloy where X is a material selected from the group consisting of Pd, Ir, Rh, Ru, and alloys thereof, or a Pt—Mn—X' alloy where X' is a material selected from the group consisting of Pd, Ir, Rh, Ru, Au, Ag, and alloys thereof. When the antiferromagnetic layer is made of one of the above-cited materials, the

antiferromagnetic layer needs to be subjected to a heat treatment to generate an exchange coupling magnetic field in the interface with the pinned magnetic layer.

[0402] FIG. 33 shows a conventional magnetoresistive-effect device having its hard bias layers and electrode layers on only both sides of the multilayer film. The width dimension A of the top surface of the multilayer film of the conventional magnetoresistive-effect device is measured using an optical microscope as shown in FIG. 31. The magnetoresistive-effect device is then scanned across a micro track having a signal recorded thereon, on a recording medium in the direction of the track width, and a reproduction output is detected. A top width dimension of B giving an output equal to or greater than 50% of a maximum reproduction output is defined as the sensitive region E and a top width dimension of C giving an output smaller than 50% of the maximum reproduction output is defined as the insensitive region D.

[0403] Based on these measurement results, a lift-off resist layer **162** is formed on the multilayer film **161**, paying attention to the width dimension C of the insensitive regions D and D measured through the micro track profile method. Referring to FIG. 15, undercuts **162a** and **162a** are formed on the underside of the resist layer **162**. The undercuts **162a** and **162a** are formed above the insensitive regions D and D, and the sensitive region E of the multilayer film **161** is fully covered with the resist layer **162**.

[0404] In a next manufacturing step shown in FIG. 16, both sides of the multilayer film **161** are etched away.

[0405] When one of the magnetoresistive-effect devices shown in FIG. 11 through FIG. 14 is manufactured, the protective layer is formed on top of the multilayer film **161**, and the resist layer **162** is formed on top of the protective layer. The portions of the protective layer, which come just below the undercuts **162a** and **162a** of the resist layer **162**, namely, the portions of the protective layer which are not in direct contact with the resist layer **162**, are removed through an obliquely entering ion milling beam to expose the layer beneath the protective layer.

[0406] In a manufacturing step shown in FIG. 17, hard bias layers **163** and **163** are deposited on both sides of the multilayer film **161**. In this invention, the sputtering technique, used to form the hard bias layers **163** and **163** and electrode layers **165** and **165** to be formed subsequent to the formation of the hard bias layers **163** and **163**, is preferably at least one sputtering technique selected from an ion-beam sputtering method, a long-throw sputtering method, and a collimation sputtering method.

[0407] In accordance with the present invention, as shown in FIG. 17, a substrate **160** having the multilayer film **161** formed thereon is placed normal to a target **164** having the same composition as that of the hard bias layers **163** and **163**. In this setup, the hard bias layers **163** and **163** are grown in a direction normal to the multilayer film **161** using the ion-beam sputtering method, for instance. The hard bias layers **163** and **163** are not grown into the undercuts **162a** and **162a** of the resist layer **162** arranged on the multilayer film **161**. Less sputter particles are deposited in the regions of the hard bias layers **163** and **163** in contact with the multilayer film **161**, because of the overhang by both end portions of the resist layer **162**. The thickness of the hard